THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

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	Page
General	
Metals Handbook: Supplement	162
'Engineering Alloys' Handbook	162
Effect of Surface Films on Intermetallic Contact under Pressure	162
Glossary of Terms Relating to Mechanical Properties and Tests	163
Nickel	
Determination of Nickel in Effluents	163
Nickel–Carbonyl Compounds	163
Electrodeposition and Other Coating Methods	
Stress in Electrodeposited Coatings	163
Machining of Heavy–Nickel Deposits	165
Plating and Finishing Data Sheets	165
Plating of Zinc–base Die Castings	166
Electroless Nickel Plating: The Kanigen Process	166
Properties of Electroless Nickel Coatings	167
Electroless Plating on Non–Ferrous Bases	168
Electroless Nickel Plating in Germany	168
Non-Ferrous Alloys	
Sintered Nickel–Copper–Cobalt Alloy Magnets	168
Magnetic Properties of Nickel–Platinum and Nickel–Palladium Alloys	168
Cast Iron	
Nickel–Alloy Cast–Iron Pots for Melting Zinc Alloys	169
Constructional Steels	
American Iron and Steel Institute Alloy Steels	169
Compression Yield–Stress Tests on Steels and Non–Ferrous Alloys	169
Fatigue of Nickel–Chromium–Molybdenum Steel: Effect of Over–Stressing	169
Effect of Grinding on Fatigue Strength of Nickel–Alloy Steel	169

	Page
Constructional Steels (contd.)	
Weldable Nickel–Copper–Molybdenum Steel for Constructional Use	170
Cooling Rates of Flash Welds in Nickel–Alloy and Other Steels	170
Low–Alloy Steel for Pressure Vessels	170
Cast Nickel–Alloy Steel Marine Propellers	170
Spectrographic Analysis of Nickel–containing Steels and Alloys	171
Heat- and Corrosion-Resisting Materials	
Precipitation in Nickel–Chromium–base Alloys of the Nimonic Series	171
Sigma Phase: Review	171
Sigma Phase in Nickel–Chromium–Molybdenum Steel	171
Carbides in 25–20 Chromium–Nickel Steel	172
Creep Tests on Metals of High Melting Point	172
Machinability of High–Temperature Alloys	172
Influence of Notches on High–Temperature Fatigue	173
Nickel–containing Materials in the Napier Eland Turboprop Engine	173
Materials used in British Gas Turbines	173
Nickel–Chromium Alloy Coating of Forging Dies	173
X–Ray Fluorescence Analysis of Nickel–Chromium–base Alloys	174
Oxidation Tests on Coated Molybdenum Wire	174
Resistance of Metallic and Non–Metallic Materials to Attack by Gallium	175
Rare–Earth Additions to Stainless Steels	175
Influence of Cold Work on Transformations in Austenitic Steels	176
Physical Methods for Determination of Austenite and Martensite Contents of Stainless–Steel Wire	177
Nickel and Nickel Alloys in Chemical Engineering	177
Gaskets for Use with Stainless Steel	178
Stainless–Steel–Faced Aluminium Sole Plate for Laundering Irons	178
Liquid Metal Fuel Reactor Systems: Design and Materials of Construction	179

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Metals Handbook: Supplement

AMERICAN SOCIETY FOR METALS: 'Metals Handbook: Supplement to 1948 Edition.' *Metal Progress*, 1954, vol. 66, July 15, pp. 1–184.

This supplement is issued with the following explanatory note indicating the scope of the material now published:—

'The members of the Metals Handbook Committee have studied the 1948 edition of the Handbook, have selected the sections in which the greatest advancement has been made, and have determined the desirability of presenting new and additional material and information in this Supplement.'

The material is arranged and the publication is sized in a form which permits use in association with the original Handbook: the sections now issued constitute a valuable addition to available reference data on metals and alloys.

The subjects dealt with in the Supplement are indicated by the list of section titles given below:—

Metals and Applications

Selection of Constructional Steels (composition, treatment, properties, uses)
Selection of Tool Steels (composition and properties of steels for tools, dies, moulds, etc.)
Stainless Steels, wrought and cast (composition, treatment, properties, and processing, including welding)
Heat-Resisting Alloys (short- and long-time tests, design curves, impact and fatigue strengths at elevated temperatures, stability)
Nodular Cast Iron (production and processing, heat-treatment; structure, properties and applications)
Applications of Aluminium and Aluminium Alloys (aircraft, automotive, railway, marine, and other uses)
Selection of Copper and Copper Alloys (composition, properties, and uses of wrought and cast types)
Magnesium and Magnesium Alloys (production, properties and uses)
Titanium and Titanium Alloys (recent development in production and processing: applications)

Design Application

Engine Metals and Engine Wear (cylinders and liners; pistons and piston rings; camshafts and tappets; valves and valve parts; bushings, crankshafts, bearings, etc.)
Effect of Stress Concentration on Design Strength (service failures; application of basic concepts to design; means for reducing effects of stress concentration)
Shot Peening and Other Surface-Working Processes (modes of operation and effects)
Design of Ferrous Castings (grey, white, malleable, and nodular irons, and steel)
Design of Brazed Joints (brazing materials; types of joint; properties of brazed joints)

Processing and Testing

Carbonitriding (nature of the process; technique of operation; advantages and limitations, costs, etc.)
Agitation of Quenching Media (including correlation of cooling effects produced in water, oil, and molten salt)
Cost of Heat-Treatment (recommended procedures for determining costs; comparative costs of gas- and pack-carburizing)
Selection of Metal-Cleaning Methods (types of soil to be removed; cleaning media; health hazards)
Press Forming of Sheet Steel (cost and limitations)
Machining of Steel and Cast Iron (cutting speeds and tool life required to secure minimum cost or maximum production)
Machining, Joining and Finishing of Powder-Metal Parts
Steel Melting (processes and furnaces used; oxygen treatment; casting practices; melting in vacuo and in special atmospheres)
Selection of Methods for Non-Destructive Inspection (methods available; evaluation of soundness of welds; inspection and sorting methods)
Metallography (principles of the metallurgical microscope; colour photomicrography; etching and polishing procedures; phase-contrast, ultraviolet, and electron metallography).

Composition, Properties and Uses of Alloys: 'Engineering Alloys' Handbook

N. E. WOLDMAN: 'Engineering Alloys: Names, Properties, Uses.'
3rd (revised) edn., published, 1954, by American Society for Metals, Philadelphia, Pa.; 1034 pp.
Price 15 dollars.

During the seven years which have elapsed since the publication of the second edition of this well-known handbook, information on more than 7,000 new alloys has been accumulated. These additional data are incorporated in the new volume, which also embodies revisions and modifications to ensure the highest possible degree of accuracy. The author's own investigations, and the co-operation of producers and users of alloys, have combined to ensure coverage of a scope not achieved in any other handbook of its kind.

Effect of Surface Films on Intermetallic Contact under Pressure

M. COCKS: 'The Effect of Compressive and Shearing Forces on the Surface Films present in Metallic Contacts.' *Proc. Physical Soc., Sect.B*, 1954, vol. 67, Mar., pp. 238–48.

It is generally recognized that metallic friction and associated surface damage are often due in large measure to the formation of intermetallic junctions between the sliding surfaces, but relatively little is known about the manner in which the junctions form and the factors which determine their size. Intermetallic contact occurs only when the intervening surface films have been penetrated, and the present paper has for its main object a study of the conditions in which penetration occurs and of the process by which large-scale breakdown occurs.

Two electrical methods were employed to determine the extent to which oxide or other natural surface films can prevent intermetallic contact when metal bodies are pressed together. One consisted in measuring the electrical resistance of the contact, the other in measuring the thermoelectric force which arises when there is a temperature gradient across the film. Crossed cylinders of various materials (having varying surface condition) were used as the contact members: the experimental apparatus is described and illustrated. Nickel (turned, lapped, or electrolytically polished), stainless steel, brass, molybdenum, tungsten, copper, gold, silver and palladium were tested in one or more sections of the investigation.

Glossary of Terms Relating to Mechanical Properties and Tests

J. B. CAMPBELL (Compiler): 'Mechanical Properties and Tests of Common Engineering Materials.' *Materials and Methods Manual No. 106; Materials and Methods*, 1954, vol. 40, July, pp. 109–32.

This Manual comprises an alphabetically arranged glossary covering mechanical properties and the tests by which they are determined, together with a few auxiliary terms essential to understanding of other entries. In appropriate cases, attention is directed to relevant schedules issued in the A.S.T.M. series of specifications and advisory publications.

Physical Methods for Determination of Austenite and Martensite Contents of Stainless-Steel Wire

See abstract on p. 177.

NICKEL

Determination of Nickel in Effluents

D. G. GARDNER, E. J. SERFASS and R. F. MURACA: 'Analytical Determination of Trace Constituents in Metal-Finishing Effluents. V. The Colorimetric Determination of Nickel in Effluents.' *Plating*, 1954, vol. 41, July, pp. 782–4.

The paper reports results of co-operative investigations by the American Electroplaters' Society and the Ohio River Valley Water Sanitation Commission.

The method described (applicable for estimation of 5–50 p.p.m. of nickel in effluents), is based on treatment with hot, concentrated acids, to remove organic matter, and extraction of the nickel content of the sample as the dimethylglyoxime complex with chloroform. The intensity of the nickel dimethylglyoxime complex is measured with a colorimeter after its extraction from the chloroform solution. This procedure has been found to yield satisfactory results in the presence of as much as 5,000 p.p.m. of each of twenty-three cations in simultaneous admixture, as well as in the presence of organic materials. If the composition of the effluent to be analyzed is known the procedure can be modified: in particular, it may be considerably shortened if the concentration of cobalt, copper, chromium, iron, and manganese is below 15 p.p.m. for each element. Full details of the normal method, and of modifications suitable for analysis of samples of known composition, are given.

Creep Tests on Nickel

See abstract on p. 172.

Compression Yield-Stress Tests on Steels and Non-Ferrous Alloys

See abstract on p. 169.

Nickel-Carbonyl Compounds

E. R. H. JONES, G. H. WHITHAM and M. C. WHITING: 'Researches on Acetylenic Compounds. Part XLIV. The Reaction between Nickel Carbonyl and some Esters of ω-Acetylenic Acids.' *Jnl. Chemical Soc.*, 1954, June, pp. 1865–8.

'Reaction of esters of ω-acetylenic acids with nickel carbonyl provides a simple route to half-esters of α-methylenedicarboxylic acids.'

H. W. B. REED: 'The Catalytic Cyclic Polymerization of Butadiene.' *ibid.*, pp. 1931–41.

The dimerization of butadiene to *cyclo*octa-1 : 5-diene is catalyzed by bistriphenylphosphinedicarbonylnickel° in the presence of acetylene. Complexes of nickel carbonyl with trimethyl or triphenyl phosphite catalyze the dimerization without added acetylene, but are more active in the presence of acetylene.

Liquid Metal Fuel Reactor Systems: Design and Materials of Construction

See abstract on p. 179.

Effect of Surface Films on Intermetallic Contact under Pressure

See abstract on p. 162.

ELECTRODEPOSITION AND OTHER COATING METHODS

Stress in Electrodeposited Coatings

R. A. F. HAMMOND: 'Stress in Electrodeposits.' *Bull. Inst. Metal Finishing*, 1954, vol. 4, Summer, pp. 145–62; *Trans. Inst. Metal Finishing*, 1954, vol. 30.

The author opens with a historical review and a resumé of views which have been advanced with regard to the causes and effects of stress. This is followed by a comprehensive and critical discussion of methods which may be used for measurement of stress in coatings: the description of the various procedures is illustrated by a series of sketches.

The third section of the paper comprises a correlation of information extracted from the literature relating to stress found in various types of coating electrodeposited under specific conditions. Nickel and chromium coatings have been more extensively studied than deposits of other types and the information given with regard to these two metals is more detailed than that for cadmium, cobalt, copper, iron,

Table I
Effects of Changes in Bath Composition on the Stress in Nickel Electrodeposits

No.		Stress p.s.i.	Variable
1	Watts nickel made up with commercial salts (pH 3·0)	32,000	
2	No. 1 purified with H_2O_2 and carbon and electrolyzed (pH 3·0)	15,000	Impurities
3	Purified Watts nickel (pH 6·0)	24,500	pH
4	Electrotyping–bath containing NH_4^+ (pH 5·8)	16,000	
5	Electrotyping–bath containing NH_4^+ (pH 6·2)	15,000	pH
6	Electrotyping–bath containing NH_4 (pH 6·8)	33,000	
7	Purified Watts bath containing 1 g./L. H_2O_2 (30%) (pH 4·2)	Very high (off scale)	
8	No. 7 after standing for 1 hour at 54°C.	62,000	H_2O_2
9	No. 7 after standing overnight at 54°C.	15,000	
10	No. 9+1 g./L. Nacconol E.P. and 0·02 g./L. cinchonine (pH 4·2)	36,000	Wetting agent and organic brightener
11	No. 10+2 g./L. saccharin	4,500	Saccharin
12	No. 11+additional 2 g./L. saccharin	2,700	
13	2–N nickel chloride solution (pH 5·0)	31,000	Chloride

NOTE.—All deposits 0·0006-in. thick.

lead, rhodium, silver and zinc. The data on nickel coatings are reproduced below.

'*Nickel*

Within the normal operating ranges, variations in temperature or in current density have little effect on stress, although at temperatures below 30°C. and at very low current densities the stress is markedly increased.

BRENNER and SENDEROFF have investigated the effect of bath composition, addition agents and pH of Watts-type double-salt solution and the results are summarized in the Table above, which is reproduced from their paper (*Proc. Amer. Electroplaters' Soc.*, 1948, vol. 35, p. 53).

'The presence of impurities in a solution made up from commercial salts increases the contractile stress; increasing pH at values approaching the highest operating range in both Watts and double-salt solutions causes an increase in stress, although, as shown by Hothersall, the converse is true at the acid end of the pH range.

'Hydrogen peroxide additions (1 g./L. H_2O_2) cause a very marked increase in stress in purified Watts solution operated at pH 4·2: so also does the addition of certain wetting agents and organic brighteners. Saccharin additions produce a marked reduction in stress (cf. the effect of sodium naphthalene trisulphonate reported by HOTHERSALL and GARDAM: *Jnl. Electrodepositors' Tech. Soc.*, 1939, vol. 15, p. 127). The chloride ion has a tendency to increase the tensile stress.

'These results are in general agreement with results published by other workers, e.g., SODERBERG and GRAHAM (*Proc. Amer. Electroplaters' Soc.*, 1947, vol. 34, p. 74), and PHILLIPS and CLIFTON (*ibid.*, p. 97).

'On account of the tendency to brittleness of bright nickel deposits, internal stress may give rise to porosity due to cracking. The following Table, derived from Soderberg and Graham's paper (*loc. cit.*) is therefore of interest, since it shows the wide variation in stress which may be obtained from commercial bright-nickel solutions.'

Table II
Stress in Nickel from Proprietary Baths
(140°F., 50 amp./sq. ft., recommended pH)

Bath	Type	Stress 1000 p.s.i.
A	Bright	−1·1
B	Bright	9·6–12·0*
C	Bright	10·0
E	Semi–Bright	19·8
F	Semi–Bright	25·6

* Excessive brightener content.

The author points out that no satisfactory explanation of internal stress in electrodeposits has yet been advanced.

'It would appear that it can be attributed to no single factor and that, even in the same metal, more than one factor may operate simultaneously, either additively or in opposition. In general, however, the explanations which appear in the literature postulate that the metal ions are discharged to form either metal atoms, or systems of metal atoms with co-deposited non-metallic matter, in a metastable form. A very rapid (possibly instantaneous) readjustment toward the equilibrium form of the metal then occurs which, if it is accompanied by a volume change, and if the deposit is adherent to the basis metal, induces internal stress (tensile or compressive as the case may be) in the electrodeposit.'

The author considers, individually, the pros and cons of the various theories which have been advanced, viz., co-deposited hydrogen, the influence of overvoltage, structural factors (hardness and grain size; crystal form, orientation and basis-metal effect); the effect of organic colloids.

Finally, attention is directed to the occurrence of compressive stress in zinc deposits, which, unlike the tensile stress occurring in deposits of other metals, develops relatively slowly and increases for some days after completion of deposition.

Machining of Heavy-Nickel Deposits

N. ZLATIN and W. H. PRINE: 'Increase Tool Life in Machining Nickel Plate.' *Iron Age*, 1954, vol. 173, July 1, pp. 118–20.

This report is based on co-operative research by Metcut Research Associates, Cincinnati and The International Nickel Company Inc., carried out with the object of determining the machining characteristics of the types of nickel deposit used for maintenance and repair of engineering components, and of standardizing the optimum conditions for machining of parts so treated.

Machining of nickel plating is usually a finishing operation in which, with correct control of plating thickness, depth of cut would be 0·005 in. or less. The tests made by the authors consisted of turning successive layers on nickel deposits plated onto carbon steel, in thicknesses ranging from 0·050 to 0·070 in. The average hardness of the 'hard' deposits was Rockwell C 43: that of the 'soft' deposits averaged Rockwell B 79.

Measurements of the rate of work-hardening of the deposits on machining, made as a preliminary in the test programme, indicated that the hard nickel showed no signs of work-hardening, but that on the soft deposit there was some effect of machining. This fact was not, however, considered to be of major importance, since the majority of the tests were made on hard plating, as being more representative of the grade used in salvage and maintenance work.

Tool-life tests were made, on the hard plating, with carbide, cast-alloy, and high-speed steel tools, and a wide variety of carbide tool compositions was tested, over a range of cutting speeds. In these tests a tungsten-carbide type gave the best results, but even with such tools the life was only five minutes at a cutting speed of 40 f.p.m. Neither change in the geometry of the tool, nor the addition of a water-base cutting fluid effected any improvement in tool performance, and changing the feed, over the range 0·005 to 0·020 i.p.r. had no major influence on life. Tool life with high-speed steel or cast-alloy tools was, however, considerably longer, e.g., to obtain a 10-minute tool life, cutting speed for the carbide tool would require to be less than 50 f.p.m., whereas with high-speed steel tools a speed of 100 f.p.m. could be used, and with the cast-alloy tool a feed of over 200 f.p.m. could be allowed.

The authors illustrate the results of the various tests by graphs and tables, and on the basis of the observations made, they put forward the following recommendations:—

'How to Machine Nickel-Plated Parts

Use high-speed steel tools, at cutting speed of 100 f.p.m. on hard nickel deposits, or cast alloy tools at 150 f.p.m.

Increase cutting speed 50 per cent. for soft nickel plate.

Best all-round tool geometry is:—

Back rake	0°	Side rake	10°
Side cutting edge angle	10°	End cutting edge angle	5°
Relief	5°	Nose radius	0·002 in.

Best surface finish is with feed of 0·002 i.p.r.

For best combination of tool life *vs.* surface area machined, use a feed range of 0·010 to 0·015 i.p.r.

Water-base cutting fluids are recommended.'

Plating and Finishing Data Sheets

'Metal Cleaning and Finishing Handbook.'
Iron Age, 1954, vol. 174, July 29, pp. F.1–F.72.

This special supplement comprises a series of data sheets and articles containing ready-reference information on the following subjects:—

- Spot Tests for Identification of Metals
- Phosphate Surface Treatments
- Surface Treatments for Aluminium Alloys and Magnesium Alloys
- Chemical Conversion Coatings: Summary of U.S. Government Specifications
- Metal-Conditioning Treatments: Summary of U.S. Government Specifications
- Electrolytic Cleaning Operations for Non-Ferrous Metals and Steels
- Pickling, Degreasing, Cleaning and Descaling Operations; Comparative data on Materials used and Techniques
- Acid Pickling and Bright-Dip Treatments
- Electrolytic Pickling Treatments
- Chlorinated Solvents
- Etching Procedures
- Infrared and Convection Drying Processes
- Non-Metallic Coatings; physical properties
- Deburring and Finishing Operations
- Shot and Grit used for Cleaning and Polishing
- Selection of Power Brushes
- Rust Preventives: U.S. Government Specifications
- Plating Processes—
  - Metallic Coatings: U.S. Government Specifications
  - Characteristics of Electrodeposited Coatings
  - Stripping of Metallic Coatings
  - Nickel Immersion Coatings

Electrodeposition of Nickel: Preparatory treatments and deposition technique for nickel-plating of various metals
Plating to Specification; conditions giving specified thicknesses of nickel and 11 other metals at known current densities
Methods of Measuring Thickness
Chromium Plating: properties
Metal-Cleaning Problems
Terms used in Metal Cleaning and Finishing: alphabetical glossary

Plating of Zinc-base Die Castings

'Nickel and Chromium Plating of Zinc-base Die Castings.' *Electroplating*, 1954, vol. 7, July, pp. 257-62.

This article is adapted from 'Chromium Plating', by P. MORISSET, J. W. OSWALD, C. R. DRAPER, and R. PINNER, recently published by Robert Draper, Ltd., London. Price 78/-.

The usefulness of zinc-base die castings as engineering materials is emphasized, and the range of alloys available for such parts is demonstrated by a table showing typical compositions and properties. The authors then describe, in logical sequence, the processes suitable for preparing the die-cast parts for plating:—polishing, degreasing, electrolytic cleaning, and acid dipping.

Details are subsequently given of the composition of the baths and operating conditions for production of the nickel-strike coating, the copper undercoat, and the final nickel and chromium coatings. Although the most durable coatings on zinc-base die castings are obtained by the nickel-copper-nickel-chromium cycle, direct chromium plating of such parts is used in some cases. Details of procedure are given.

The article includes a summary of the following standard specifications for nickel-chromium plating of zinc and zinc alloys:—British Standard 1224: 1953, American Society for Testing Materials B-142-53, and German D.I.N. Specification 50 964: 1951.

Electroless Nickel Plating: The Kanigen Process

G. GUTZEIT: 'Kanigen Nickel Plating.'
Metal Progress, 1954, vol. 66, July 1, pp. 113-20, 146.

'Kanigen' plating is a trade mark used by General American Transportation Corporation for its process of electroless nickel plating, which is based on the research carried out by Brenner and Riddell at the National Bureau of Standards.

This comprehensive article opens with an account of the basic principles of the process as originally developed at the Bureau, giving particulars of the baths then employed and of the reactions occurring. While it was obvious from the outset that the process was of considerable potential value, it was found that certain limitations were inherent:—lack of stability of the bath in continuous working, rough and dull plating after initial production of satisfactory deposits, slow rate of plating, formation of a stratified (non-homogeneous) deposit, and relatively high cost.

General American Transportation Corporation has, since 1952, been engaged in research and development designed to overcome these limitations, and to evolve plating conditions which will give consistently satisfactory results on a commercially economic basis. Experiments with many variants of the basic bath have proved that the concentration of the components of the solution, and strict control of initial pH, are critical in the acid electroless baths. If the nickel: hypophosphite ratio is below 0·25 the deposit is of a dull grey, non-metallic appearance: if the ratio exceeds 0·6 the rate of deposition falls off badly. A high concentration of hypophosphite ions results in instability, while a low anion concentration slows down deposition. Even under optimum conditions, plating rate with baths only slightly modified from the original composition is too slow to meet the requirements of industry, but it has been found that the addition of certain organic anions (e.g., unsubstituted short-chain aliphatic dicarboxylic acids) will substantially increase the speed of deposition, and that with such additions bath stability in batch operation is improved. The effect of such reagents is to loosen the bond of the hydrogen atoms attached directly to the phosphorus atom in the hypophosphite molecule, by complex formation.

Continuous circulation, filtration, and regeneration are necessary to keep the composition of the bath constant and to secure homogeneous deposits: the plating system incorporating equipment for ensuring such conditions is described and illustrated in this paper. Its salient features are the subject of patents, to which reference is directed. It was found that the continuous heating and cooling involved in operation of the plating cycle described was liable to cause thermal decomposition, with the result that after a certain number of cycles the bath became unstable. This observation led to the development of specific stabilizers, some of which, in addition to fulfilling their principal function, have a favourable influence on the rate of deposition and the appearance of the coating. The bath thus developed and processed is stable and brilliantly clear, maintaining a constant composition.

The principal properties of Kanigen plating are summarized as follows:—

'*Chemical composition* (average): 7% phosphorus, 92% nickel.
Hardness (as deposited): Vickers 500 (about Rockwell C-49).
Corrosion-Resistance: At least equal to and generally better than that of wrought nickel.
Coefficient of Expansion: 13×10^{-6} in. per in. per °C. *or* $7{\cdot}22 \times 10^{-6}$ in. per in. per °F.
Electrical Resistivity: Approximately 60 microhms per cm.
Adherence: Excellent on steel and copper alloys; good on ferrous alloys, aluminium, and thermosetting plastics.
Porosity (as deposited): No porosity for minimum thickness of 0·2 mil.
Melting Point: Between 2000° and 2190°F. (1095° and 1200°C.).

With the standard acid solutions, the coating averages 7 per cent. phosphorus. It is highly probable that the phosphorus is present as a solid solution in nickel, and that the deposit is amorphous (as shown by chemical tests and X-ray diffraction).

'By heat-treating at 750°–930°F. (400°–500°C.) for 1 hour in a reducing or inert atmosphere, the hardness can be raised to from Vickers 500 or 600 to 900 (Rockwell C-64). A heat-treatment at about 1110°F. (600°C.) for 1½ hours results in a hardness, at room temperature, of Vickers 700, but the ductility is increased, so that wear-resistance is improved.

'Heat-treatment at about 1470°F. (800°C.) for 1 hour will produce a room-temperature hardness equal to or below the original value, depending on the kind of plating bath used. Thus, one kind of coating will have a hardness of Vickers 250 after 1 hour, with good ductility, permitting considerable bending without stress failure. The hot hardness of Kanigen above 750°F. (400°C.), (i.e., the hardness at elevated temperature) is low, and coated parts are unsuitable for applications above this temperature, particularly where abrasion is involved. The hardness of the coating usually gives good abrasion resistance, particularly under lubricated conditions.'

The corrosion-resistance of Kanigen nickel-phosphorus plate is claimed to be at least equal to that of electrodeposited nickel: typical behaviour in 75 per cent. caustic soda solution, fluorophosphoric acid, crude oil, naphtha, acetylene bromide, and photographic developing solutions is quoted in support of this statement, and good resistance to attack by the standard salt-spray test is reported. An important characteristic of the Kanigen coatings in salt-spray is that when rust spots appear they do not spread as do the spots appearing in electrodeposited nickel coatings.

Adhesion of the Kanigen deposits to low-carbon steel, copper alloys, and nickel is described as 'excellent': bend and tensile test results are quoted. By means of special pre-plating treatment of the basis metal, good adhesion on aluminium and on alloy steels (including stainless types) is obtainable. On thermosetting plastics, ceramics, and glass adhesion varies from good to fair, according to the nature of the basis material. Developments in preparatory treatment of non-metallic surfaces is the subject of a pending patent application.

When deposited on a metal of reasonably good quality, Kanigen coatings are non-porous at thicknesses of 0·2 mil and above. Four experimental porosity-testing methods which have been applied to the deposits are described. This type of coating cannot be applied on lead, cadmium, zinc, tin, or antimony, nor on surfaces which have been contaminated with such metals, a fact which precludes its use on parts soldered or brazed with tin or lead alloys. Chemical plating on zinc-base die castings is best done over an undercoating of copper. Direct plating on magnesium is still in the experimental stage.

Uniformity of the deposits can be closely controlled, and thickness may be varied within wide limits, but it is considered undesirable to exceed 6–7 mils. In a non-corrosive medium full protection is afforded by 0·5–1 mil; in mildly corrosive conditions a thickness of 5 mils is usually sufficient to confer protection in liquids or gases for which the Kanigen deposits are inherently suitable. The colour of the coatings is a metallic light grey with a yellow tinge: by means of a special additive medium a white colouration is produced, without increasing the optical coefficient of reflection. An after-treatment has been developed to blacken the surface of Kanigen deposits.

The suitability of this process of deposition for coating of parts of irregular shape has already been repeatedly emphasized; typical applications include tanks, complex fabricated assemblies, parts having screw threads, indentations or holes, and interior surfaces of vessels which are difficult to plate by electrodeposition. Parts carrying Kanigen coatings can be soldered with ease, provided that the temperature is sufficiently high to ensure flow.

Costs of Kanigen plating cannot in most cases be directly compared with those involved in electrodeposition of nickel by standard methods, since many of the applications are suitable to one or the other, not to both. Where it is possible to employ either method, electroplating is at present somewhat cheaper, but in some of these instances Kanigen plating has the advantage that costs may be reduced by use of a thinner coating. The high corrosion-resistance and superior hardness of the nickel-phosphorus coatings indicate their use in many applications for which the properties of electrodeposited nickel would not be adequate.

The review is supported by references to technical and patent literature.

Properties of Electroless Nickel Coatings

A. E. DURKIN: 'Extend Applications of Nickel Immersion Plating.' *Iron Age*, 1954, vol. 173, July 8, pp. 91–4.

The aim of this article is to outline the properties obtainable in phosphorus-containing nickel coatings produced by the electroless process. After an introductory discussion of the reactions involved in this process, and of the value of electroless plating in treatment of parts of complex shape, the author gives factual information on properties which are being obtained in coatings so produced.

A unique characteristic of the nickel immersion coating is its capacity for hardening by heat-treatment, resulting from the presence of phosphorus. In the as-deposited condition the hardness is Rockwell C 45, and by heating for one hour at 750°–1000°F. (400°–540°C.) this can be increased to 65–70 Rockwell C. Intermediate values can be produced by heating at lower temperatures. Exposure to temperatures above about 950°F. (510°C.) tends to soften the deposit, but up to 1400°F. (760°C.) it retains the as-plated degree of hardness. Extended heating below 1000°F. (540°C.) causes only about 10 per cent. reduction from the hardness value of the heat-treated deposit. When heated above 500°F. (260°C.) the coatings tend to stain: if such surface change is objectionable, heat-treatment should be carried out in a non-oxidizing atmosphere or in a neutral salt bath.

Tests on nickel-phosphorus immersion-coated pins, in comparison with chromium-plated pins, showed the electroless coatings to be markedly resistant to fretting corrosion. Immersion coatings in the as-plated condition raised the fatigue strength of a low-alloy chromium-molybdenum steel only to an insignificant extent: when the coated specimens had

been heat-treated after plating they had a deleterious effect on fatigue strength. Untreated chromium plating had a similar influence. Salt-spray and humidity tests lead to the conclusion that the resistance of the nickel-phosphorus coatings compares favourably with that of nickel and chromium deposits made by conventional plating procedures. Atmospheric weathering tests gave inconclusive results: in some inland areas the immersion coatings withstood exposure for a year without failure, but resistance to marine atmospheres appears to be much less satisfactory.

Electroless Plating on Non-Ferrous Bases

H. J. WEST: 'Electroless Nickel Plating on Non-Ferrous Metals.' *Metal Finishing*, 1954, vol. 52, July, p. 72.

This article describes procedure for immersion plating of aluminium, brass, copper, and titanium. It is stated to be suitable also for plating of stainless steel.

Instead of the acid type of solution, which can be used in electroless plating of steel, an alkaline bath is employed. The following formula is given, and may be proportionally increased for larger baths:—

Sodium citrate	6 lb.
Ammonium chloride ..	4 lb.
Nickel chloride	2½ lb.
Sodium hypophosphite ..	10 oz.
Ammonium hydroxide ..	500 cc.
Water	10 gall.

A pH of approximately 10 should be maintained by means of continuous additions of ammonium hydroxide: the author recommends that, both for racked parts and in barrel plating, an addition of 500 cc. be made after treating each equivalent of 30 sq. ft. of work. Tank pots or linings should be of glass or porcelain: racks should not be treated with organic coatings, plain steel racks are to be preferred. High-temperature Lucite may be used for barrels, and plating should be carried out at 180°–190°F. (83°–88°C.), preferably at the lower end of that range for barrel plating.

Parts to be treated by the electroless process are cleaned and processed as in ordinary electroplating, but aluminium should be placed in the plating solution immediately after cleaning, or allowed to remain immersed in cold water until put into the bath. A small amount of aluminium sulphate (about 1/100 oz.) may usefully be added to the bath immediately before plating a batch of aluminium, but this is not required when treating copper and copper alloys. Titanium reacts in the same way as aluminium; some alloying may occur, with resulting formation of a coating of nickel, phosphorus, and titanium. A violent reaction occurs during plating and as this subsides the pH falls and addition of ammonium hydroxide is necessary. Brass, copper and other copper-base alloys coat easily and effectively.

The alkaline solution, unlike the acid type, need not be discarded at the end of a day's work, but may be used continuously, provided that suitable additions are periodically made. After a full day's work the nickel chloride must be replenished, and at the end of 16 hours' continuous working all ingredients must be replenished, or a portion of a mixture to the original formula may be added to the existing solution.

Electroless Nickel Plating in Germany

'Electroless Nickel Plating by the Nirestan Process'. *Metall*, 1954, vol. 8, June, p. 472.

Immersion plating by a method based on the work of BRENNER and LIDDELL is being developed in Germany under the name of 'Nirestan'. This article briefly describes the basic principles of the process, and the nature and uses of the nickel-phosphorus coatings producible by it.

NON-FERROUS ALLOYS

Sintered Nickel-Copper-Cobalt Alloy Magnets

W. RUTKOWSKI: 'Sintered Permanent Magnets. I. Sintered Permanent Magnets without Aluminium. *Prace Inst. Minist. Hutnik*, 1954, vol. 6, No. 1, pp. 50-6; abstract in *Metallurgical Abstracts*, 1954, vol. 21, July, p. 947.

'The author describes preparation of magnets by sintering of mixed powders: best results were obtained with mixtures containing copper 45, cobalt 30, nickel 25, per cent.

Metals Handbook: Supplement

See abstract on p. 162.

Composition, Properties, and Uses of Alloys: Handbook

See abstract on p. 162.

Magnetic Properties of Nickel-Platinum and Nickel-Palladium Alloys

E. P. WOHLFARTH: 'The Magnetic Properties of Alloys of Cobalt and Nickel with Palladium and Platinum.' *Philosophical Magazine*, 1954, vol. 45, June, pp. 647-9.

In discussion on earlier papers relating to the magnetic properties of alloys of platinum with cobalt or nickel it had been suggested that the ferromagnetism of platinum-rich cobalt alloys might arise as a result of strong intra-atomic exchange forces in the cobalt atoms, or, alternatively, that there might be some exchange interaction between cobalt and platinum atoms. In order to interpret the difference between the properties observed in cobalt-platinum and nickel-platinum alloys, it was suggested that the intra-atomic exchange forces in nickel may be much less pronounced than in cobalt, in agreement with the fact that the Curie temperature of nickel is lower.

The present note comprises a more detailed discussion of the subject: it also reports measurements of the magnetic properties of some analogous cobalt-palladium and nickel-palladium alloys. The observations made are interpreted on the basis of three of the ideas underlying the collective electron treatment of magnetism.

Spectrographic Analysis of Nickel-containing Steels and Alloys

See abstract on p. 171.

Compression Yield-Stress Tests on Steels and Non-Ferrous Alloys

See abstract on p. 169.

CAST IRON

Nickel-Alloy Cast-Iron Pots for Melting Zinc Alloys

'Nickel Cast Iron Pots Last Longer Melting Non-Ferrous Alloy.' *Nickel Topics*, 1954, vol. 7, No. 6, p. 4.

Cast iron pots used for melting Kirksite, a white-metal die alloy, were found to give very short service life, due to heat-checking and the corrosive action of the molten metal. Following considerable research on modification of the material for the pots, it has been found that by the use of a nickel-alloy cast iron life can be increased by 300–400 per cent. The composition recommended includes nickel about 2, chromium 0·85, silicon 1·55–1·70, manganese 0·75 per cent. By means of a normalizing treatment before putting into service, a hard adherent surface scale is formed on surface of the pots, inhibiting corrosion by the molten alloy and minimizing thermal effects.

Metals Handbook: Supplement

See abstract on p. 162.

Composition, Properties, and Uses of Metals and Alloys: Handbook

See abstract on p. 162.

CONSTRUCTIONAL STEELS

American Iron and Steel Institute Alloy Steels

'A.I.S.I. Standard Alloy Steel Compositions.' *Metal Progress*, 1954, vol. 66, July 1, p. 112B.

This list, revised as of February, 1954, gives the composition limits standardized for open-hearth and electric-furnace low- and medium-alloy steels. It covers bars, billets, blooms and slabs up to 200 sq. in., 18 in. wide, or 10,000 lb. in weight. The lists include nickel, nickel-chromium, nickel-chromium-molybdenum, and nickel-molybdenum steels.

Compression Yield-Stress Tests on Steels and Non-Ferrous Alloys

R. B. SIMS: 'Yield-Stress/Strain Curves and Values of Mean Yield Stress of Some Commonly Rolled Materials.' *Jnl. Iron and Steel Inst.*, 1954, vol. 177, Aug., pp. 393–9.

Methods for calculating the load and torque applied to the rolls of a cold-reduction mill may be based empirically on the results of experiments, or obtained from theoretically derived measurements. Although the latter is obviously the more reliable method, there is relatively little information on which the necessary calculations can be made. As a contribution to amplification of such necessary data, the author presents information on yield stress in plane compression (obtained in the course of research on cold-rolling), together with values for mean yield stress. The experimental method used for measurement of yield stress in plane compression is described, and its accuracy, by comparison with tensile tests, is discussed.

The materials for which the above values are recorded are: various types of carbon steel, low-silicon steels, a 17 per cent. chromium-iron alloy, 18–8 chromium-nickel steel, aluminium alloys, 70–30 brass, Monel, nickel silver, nickel, and Nimonic 80 alloy.

Metals Handbook: Supplement

See abstract on p. 162.

Composition, Properties, and Uses of Steels: Handbook

See abstract on p. 162.

Fatigue of Nickel-Chromium-Molybdenum Steel: Effect of Over-Stressing

G. E. DIETER, G. T. THORNE and R. F. MEHL: 'Statistical Study of Overstressing in Steel.'
Nat. Advisory Committee for Aeronautics, Tech. Note 3211, Apr., 1954; 34 pp.

Effect of overstressing, on fatigue properties, was statistically studied in a nickel-chromium-molybdenum steel of the following composition: carbon 0·35, silicon 0·27, manganese 0·83, nickel 1·82, chromium 0·77, molybdenum 0·37, per cent. Investigation of the influence of microstructure, on susceptibility to reduction in fatigue life resulting from cycles of overstress, showed that when tested at equivalent per cent. stress, the steel having a quenched and spheroidized structure was more susceptible to fatigue damage than the same material in the quenched-and-tempered condition.

The curve of damage *vs.* cycle ratio obtained by the statistical tests agrees with data reported in the literature in non-statistical investigations, indicating that, in general, results of non-statistical studies may be regarded as valid. The effect of cycles of overstress on endurance limit is shown, by the statistical evaluation, to be far greater than had been previously reported. Endurance limit is markedly lowered by a relatively small number of cycles of overstress, which is interpreted as further evidence that fatigue damage (and probably the fatigue crack) occurs early in total life of a fatigued specimen.

Effect of Grinding on Fatigue Strength of Nickel-Alloy Steel

D. N. CLEDWYN-DAVIES: 'Effect of Grinding on the Fatigue Strength of Steels.' *Engineer*, 1954, vol. 198, Aug. 20, pp. 270–2.

The work described in this paper (contributed for discussion by the Institution of Mechanical Engineers) comprises an attempt to provide, for industry, information on the effect of grinding on the fatigue strength of some steels commonly used for constructional purposes. The fatigue tests were made on a rotating uniform bending moment machine running at a speed of 4,000 r.p.m.

The materials tested were a nickel-chromium-molybdenum steel heat-treated to two conditions:

(*a*) 80-ton tensile, and (*b*) 62-ton tensile, a 0·6 per cent. carbon steel, and a 0·1 per cent. carbon steel. A limited number of preliminary tests were also made on a Vibrac nickel-chromium-molybdenum steel in the 62-ton tensile condition. Details of surface preparation of the specimens, and of conditions of tensile and fatigue testing are given in the paper, together with a critical appraisal of the results of the fatigue tests. The data recorded lead the author to the following conclusions:—

The grinding of steels under good grinding conditions has no deleterious effect on fatigue strength, but poor grinding technique causes a reduction. Stress-relieving ground specimens of the Vibrac steel which showed fall in fatigue strength after grinding under unsuitable conditions did not restore the value to that of the virgin material.

Reduction in fatigue strength caused by grinding results from patches of grinding burn on the surface. In grinding fatigue specimens of the type used in this investigation, such effects are apt to occur at the lower regions of the transition radius, where cutting is taking place over the full profile of the shaped wheel.

The grinding of steels under good grinding conditions produced no more scatter of results than that obtained with turned and hand-polished specimens.

Small differences in ground surface finish (2–11 micro-inches) had no apparent effect on the fatigue strength of a hardened-and-tempered nickel-chromium-molybdenum steel, in the 62-ton tensile condition.

In the 80-ton tensile nickel-chromium-molybdenum steel even careful grinding caused a reduction in the fatigue life, although there was no reduction in the fatigue strength.

Weldable Nickel-Copper-Molybdenum Steel for Constructional Use

F. NEHL: 'Use of Time-Temperature-Transformation Data to Solve Problems Relating to the Production of Highly Stressed Welded Structures.'
Stahl und Eisen, 1954, vol. 74, Aug. 12, pp. 1054–61; disc., pp. 1061–2.

The author discusses the problems involved in achieving weldability in alloy steels characterized by the high mechanical strength desirable in structural applications.

The influence of various alloy additions and of heat-treatments involving conditions similar to the heating occurring in welding are studied on some typical steels, including low-alloy manganese, chromium-molybdenum, copper-nickel, and copper-nickel-molybdenum types.

It is concluded that a copper-nickel-molybdenum steel (*a*) develops, under welding conditions, structures which will inhibit formation of hard zones in the vicinity of the weld, and consequent cracking, and (*b*) possesses mechanical properties rendering it suitable for structural use. The composition recommended is as follows:—carbon about 0·15, manganese 1, copper 1, nickel 1, molybdenum 0·35, chromium 0·4, per cent.

Cooling Rates of Flash Welds in Nickel-Alloy and Other Steels

E. F. NIPPES, W. F. SAVAGE, G. GROTKE and S. M. ROBELOTTO: 'Study of Cooling Rates in Flash Welds in Steel.' *Welding Jnl.*, 1954, vol. 33, July, Suppl. pp. 339S–61S.

A systematic study of flash welding of steel, planned to evaluate the influence of the respective variables involved, has been in progress for some years at the Welding Laboratory of Rensselaer Polytechnic Institute. Work reported earlier has dealt with the contribution of the flashing variables to the temperature distribution at the instant of upset. The present paper covers investigation of the influence of variables in flashing and upset on the cooling rate at the weld centreline. An attempt is made to correlate the weld microstructures found and the properties of the weldments, with the metallurgical behaviour of the steels used and the weld-cooling rates.

The first part of the report describes the experimental techniques employed and the results obtained in the study of cooling rates. The second part summarizes the mechanical and metallurgical properties of welds made in carbon steel (0·18–0·23 per cent.), chromium-molybdenum steel (0·95/0·21 per cent.) and nickel-chromium-molybdenum steel (1·74/0·80/0·25 per cent.).

Low-Alloy Steel for Pressure Vessels

A. G. GRAY: 'New Steel Passes Toughness Test.'
Steel, 1954, vol. 135, July 19, pp. 102–3.

This article refers to a new steel developed by United States Steel Corporation under the name of Carilloy T-1, to meet the requirement for a particularly tough material for pressure vessels. The composition given is as follows:—carbon 0·15, silicon 0·27, manganese 1·0, sulphur 0·022, phosphorus 0·014, nickel 0·94, chromium 0·53, molybdenum 0·45, vanadium 0·05, copper 0·34, boron 0·0014, per cent., iron remainder.

Heat-treatment consists in holding for one hour at 1650°F. (900°C.), water-quenching, tempering at 1175°F. (635°C.) for one hour, and final water-quenching. It is claimed that, in the condition so produced, the steel shows, in sections up to six inches, the following minimum properties:—

	p.s.i.	t.s.i.
Yield Strength	90,000	40·2
Tensile Strength	105,000	47
Elongation, in 2 in. ..	16%	
Reduction of Area ..	45%	

Severe bursting and impact tests, at normal and at sub-zero temperature, have indicated the suitability of the steel for pressure vessels, and for other applications in which specially high toughness is essential.

Cast Nickel-Alloy Steel Marine Propellers

'Cast Nickel Steel Widely Used in Boat Propellers.'
Nickel Topics, 1954, vol. 7, No. 6, pp. 1, 5.

Propellers operating on inland waterways are subject to many underwater hazards from submerged debris, which may cause breakage or distortion. The material

selected must therefore be one which will provide an optimum combination of strength and toughness, at reasonable cost: a further requirement is that it should be capable of undergoing satisfactory repair by welding. Propellers for this type of service vary up to about 2½ tons in weight and 10 ft. in diameter: a 5-blade design typical of those used in tow-boats on the Mississippi River is illustrated in this article. It is a nickel-alloy steel casting of the composition shown below, which is reported as giving particularly good service in this type of work.

Carbon	0·12-0·15 per cent.
Silicon	0·50-0·60 „ „
Manganese	0·45-0·65 „ „
Nickel	2·00-2·50 „ „
Chromium	0·90-1·10 „ „

	p.s.i.	t.s.i.
Tensile Strength ..	82,000	36·5
Yield Strength ..	55,000	24·5
Elongation, in 2 in. ..	25%	
Reduction of Area ..	45%	
Bend Test	120°	

Spectrographic Analysis of Nickel-containing Steels and Alloys

S. MUIR and A. D. AMBROSE: 'A Solution Method of Spectrographic Analysis.'
Jnl. Iron and Steel Inst., 1954, vol. 177, Aug., pp. 400–5.

The authors describe a method of spectrographic analysis which consists of solution of the sample and impregnation of this solution with prepared graphite. Excitation is by means of an uncontrolled A.C. condensed spark. Working details are given for analysis of a number of materials, and comparisons are made with results obtained by chemical analysis. The analyzed materials included low-alloy nickel-containing and other steels, iron ore, blast-furnace slag, Monel, bearing metal, bronze, low-grade zinc, and a corrosion product.

HEAT- AND CORROSION-RESISTING MATERIALS

Precipitation in Nickel-Chromium-base Alloys of the Nimonic Series

Y. BAILLIE and J. POULIGNIER: 'Study of Sub-Microscopic Precipitation in High-Temperature Alloys of the 80-20 Nickel-Chromium Type.'
Revue de Métallurgie, 1954, vol. 51, Mar., pp. 179–90; disc., pp. 190–1.

The authors describe a technique which they have devised for producing replicas for electron-microscope examination, and record results of tests made by it on specimens of Nimonic alloys 80, 90 and 95. The alloys were examined in the normal fully heat-treated conditions, and the influence of time and temperature of heating was examined over the range 650°–900°C.

The results show that in all the alloys the number of particles of precipitate decreases with rise in the ageing temperature, and that this change is associated with increase in size of the individual particles. No relationship could be found between these changes and the creep properties of the alloys in the corresponding conditions.

Metals Handbook: Supplement

See abstract on p. 162.

Composition, Properties, and Uses of Alloys: Handbook

See abstract on p. 162.

Sigma Phase: Review

A. J. LENA: 'Sigma Phase: a Review.' *Metal Progress*, 1954, vol. 66, July 1, pp. 86–90.

A series of three articles, of which this is the first, will correlate information obtained from the most significant investigations on formation of sigma phase and its effects on the properties of alloys.

Part I covers consideration of the compositional limits of sigma formation in alloys of the stainless-steel types, i.e., basically iron-chromium and iron-chromium-nickel alloys. The boundaries of the susceptible compositions are indicated by diagrams constructed as a result of work by various investigators. The information given shows that a large number of cast and wrought alloys are capable of developing sigma: these include the standard high-alloy steels containing chromium above about 17 per cent., as well as some of the newer austenitic chromium-manganese steels. It is emphasized, however, that the possible occurrence of sigma is not always a grave danger from the practical standpoint, since in many cases considerable lengths of time are required for its development. This aspect will be discussed more fully in the second part of the review, which will deal with the influence of sigma phase on mechanical properties.

Sigma Phase in Nickel-Chromium-Molybdenum Steel

A. G. ALLTEN: 'An Fe-Cr-Mo-Ni Sigma Phase.'
Jnl. of Metals, 1954, vol. 6, Aug.; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 904–5; Tech. Note 225E.

The author reports observations on the occurrence of sigma phase in a steel of the following composition: carbon 0·06, silicon 0·38, manganese 1·26, nickel 21·15, chromium 18·72, molybdenum 9·14, tungsten 3·07, per cent.

Both the sigma phase and carbides of the M_6C type were present in the as-forged steel. The carbides dissolved completely in the austenite at approximately 2200°F. (1205°C.). The sigma phase was, however, present at all temperatures up to the solidus of the

steel at approximately 2375°F. (1300°C.). Ferrite was not found in the steel in any condition.

The observations made are correlated with the findings of various investigators who have reported data on sigma in binary and ternary alloys.

Carbides in 25-20 Chromium-Nickel Steel

H. BROWN: 'Carbides in 310 Stainless Steel.' *Steel*, 1954, vol. 135, July 19, pp. 106–8; July 26, pp. 92–4.

The article is based on observations made in the plant of Solar Aircraft Company, with regard to carbide formation in certain consignments of 25-20 chromium-nickel steel purchased from various sources. In some cases the carbides occurred in a continuous grain-boundary network, in others they were discontinuous. A carbide rating chart already in use for evaluation of unstabilized chromium-nickel steels (shown in this article) was used in examination of the 25-20 steel.

The occurrence of the carbides was studied by means of various etching procedures and an attempt was made, without success, to correlate normal tensile properties with carbide ratings. Efforts to relate carbide occurrence with Huey nitric-acid corrosion-test data also proved unfruitful.

Carbide precipitation of the type described can be produced during rolling or other processing of the steel, or by incorrect handling in fabrication, and visits to the various mills which were supplying the steel revealed that in some cases the conditions used were likely to give rise to the defect. Detailed study of material processed under known conditions established that severe carbide precipitation can be caused by: (1) annealing temperatures below 2050°F. (1120°C.); (2) slow cooling from the heat-treatment temperature; (3) stacking of parts during heat-treatment so that circulation of air is restricted during heating and cooling, (4) more occasionally, by the presence of carbon-containing water-soluble drawing compounds not removed before heat-treatment.

(The article includes a list of solutions and etching techniques used for revelation of carbides: these include the use of oxalic acid, glyceregia, chromic acid, sodium cyanide, Fry's reagent, and Marble's reagent).

Creep Tests on Metals of High Melting Point

N. P. ALLEN and W. E. CARRINGTON: 'Exploratory Creep Tests on Metals of High Melting Point.' *Jnl. Inst. Metals*, 1953–4, vol. 82, July, pp. 525–33: Advance Copy 1550.

Creep-resisting alloys used during the past ten years in gas turbines have been based, in almost all cases, on the face-centred solid solutions of iron, nickel, chromium, and cobalt, stiffened with additions of other elements. Exploration of the possibility of improving such alloys is still progressing, but in the interests of long-term development it has been felt to be desirable to determine also the strength, at high temperatures, of metals having melting points higher than that of iron. As a contribution to such research, this paper presents an investigation of the strength, at 1000°C., of the following metals, tested in the purest available forms:—titanium, zirconium, vanadium, niobium, tantalum, chromium, molybdenum, tungsten, platinum, palladium, rhodium, iridium, iron, cobalt, and nickel. Comparative data were also obtained on some sintered-carbide materials containing cobalt or cobalt-nickel-chromium as binders, on two types of nickel-chromium-base alloy, and on tungsten steel.

The method of assessment of strength was by compression creep tests made in vacuo at 1000°C., the criterion being the stress required to give 1 per cent. creep strain in 24 hours.

Plotting of high-temperature strength *vs.* atomic number of the metals resulted in a periodicity similar to that given by their melting points and elastic constants.

Machinability of High-Temperature Alloys

'High-Temperature Alloys: Air Force Machinability Report, Part IV.' *Iron Age*, 1954, vol. 174, July 22, pp. 112–14.

This article is based on tests made by Curtiss-Wright Corporation, for United States Air Force, on a series of high-temperature alloys typical of those used for gas-turbine components. Compositions are shown in the Table below. Milling operations were performed with carbide and cast-alloy cutters:

Analyses of High-Temperature Materials

Material	C %	Cr %	Ni %	Mo %	Co %	Al %	Mn %	Ti %	Nb %	Other Elements	Fe %
Stainless Steel ..	0·08	18	10	—	—	—	—	—	0·8	—	Bal.
S-816	0·4	20	20	—	43	—	—	—	4	W:4	Bal.
Inconel-X	—	15	73	—	—	0·7	—	2·5	1	—	8
Refractaloy-26 ..	0·03	18	37	3	20	0·2	0·7	2·6	—	—	Bal.
Discalloy-24 ..	0·03	13	26	3	—	0·1	0·8	1·6	—	—	Bal.
Timken 16-25-6 ..	0·07	14·6	25·3	5·9	—	—	1·5	—	—	Si:0·5	Bal.
A-286	0·05	15	26	1·45	—	1·7	—	1·6	—	V:0·2	53·5
M-252	0·10	19	53·5	10	10	0·75	—	2·5	—	—	2·0

turning was done with carbide and high-speed steel tools. Drills were of conventional high-speed steel.

The results have been correlated for presentation in the form of charts for the individual alloys, showing cubic inches of metal removed for a pre-selected degree of tool wear, at various feeds per tooth, from 0·002 to 0·012 in. Runs at several cutting speeds are given. In the tool-life tests, a single-tooth flycutter was used in climb face milling. A soluble oil cutting fluid was employed. Endpoint for cast-alloy tools was a 0·060-in. wearland: for the carbide tools a 0·015 in. wearland was used as the test criterion. For the machining tests depth of cut was 0·050-in. and the width of cut was 2 in.

Influence of Notches on High-Temperature Fatigue Properties

C. A. HOFFMAN: 'Investigation of Effect of Notches on Elevated-Temperature Fatigue Strength of N-155 Alloy.' *Nat. Advisory Committee for Aeronautics*, R. M. E53L31a, Apr. 26, 1954; 8 pp.

Report of investigation made in collaboration with the A.S.T.M.-A.S.M.E. Joint Committee on Effects of Temperature on the Properties of Metals.

The material used was of the following composition: carbon 0·13, silicon 0·42, manganese 1·64, chromium 21·22, nickel 19·00, cobalt 19·70, molybdenum 2·90, tungsten 2·61, niobium 0·84, nitrogen 0·13, per cent., iron balance. Heat-treatment comprised 1 hour at 2200°F. (1205°C.), water-quenching, ageing for 16 hours at 1400°F. (760°C.), and final air-cooling. The design of the test specimen used is illustrated, and the stress-concentration factor in bending is discussed. Complete reverse-bend tests were made at 1350° and 1500°F. (735° and 815°C.).

The results indicated that: (*a*) notches reduced fatigue strength at 1350°F. by approximately 34–40 per cent., and at 1500°F. by approximately 30–37 per cent., over the range of 3-150 hours, and (*b*) the notch-sensitivity in fatigue, under conditions of completely reversed bending at 1350° and 1500°F., was considerably less than that predicted for static bending under elastic conditions.

Nickel-containing Materials in the Napier Eland Turboprop Engine

'Napier's New Turboprop Engine.' *Aeroplane*, 1954, vol. 87, July 23, pp. 110–16.

The Napier Eland engine, which is described and illustrated in this article, represents an important contribution to contemporary gas-turbine design, embodying several features of outstanding interest. The engine, which has a rating of 3,000 e.h.p., has already undergone some 1,250 hours of bench testing and has completed its 25-hour special-category flight-approval test.

Reference to the materials of construction used for the various components emphasizes the wide variety of properties, and therefore of materials, required in a power unit of this type. In common with other British production aircraft gas turbines, Nimonic alloys are used for the rotor blades: Nimonic 90 for the first stage, Nimonic 80A for the other two. Nozzle blades are of X-40, cobalt-chromium-nickel-base alloy. Nimonic 75 has been used for the flame tubes.

Materials Used in British Gas Turbines

H. SUTTON: 'Materials for Gas Turbines.' Paper contributed to session on Scientific Research and the Changing Pattern of British Industry, held during Production Exhibition and Conference, Olympia, London, July 9, 1954; 7 pp.

The paper opens with a brief review of the collaborative effort in Great Britain which led to the development of alloys used during the war period and afterwards for the components of aircraft gas turbines. Particular attention is directed to the Nimonic series of alloys, which from the early 1940's have been standard for the rotor blading of British aircraft gas turbines. Austenitic and ferritic steels which are used in high-temperature service are also considered, e.g., G. 18B and H.R. Crown Max.

General features essential in gas-turbine materials are discussed, e.g., highest possible quality consistent with economic production; mechanical strength, structural stability and resistance to oxidation at operating temperatures; resistance to deterioration under drastic temperature changes, and reasonable capacity for machining and processing by the normal fabricating processes.

In the final section of the paper the author considers some materials and techniques which are likely to make a contribution to further development in this field.

Nickel-Chromium Alloy Coating of Forging Dies

'Brightray Coating for Forging Dies.'
Metal Treatment and Drop Forging, 1954, vol. 21, July, p. 353.

Electrical upsetting offers an economic method of providing, for drop forging or stamping, a preformed section which has the mass of metal in exactly the position in which it is needed for the dies. In an example described in this note, a stainless-steel rod is heated by passing through it a current, while pressure is applied at its ends. When the metal is sufficiently hot to become plastic it is forced up, and forms a bulbous shape suitable for drop-forging to the contours required for a gas-turbine compressor blade.

The temperatures reached in this operation are above 1000°C. Under the pressure applied, the material of the anvil is subjected to considerable thermal strain, and much difficulty has been experienced in selecting a material which would withstand the conditions involved. This article reports the application of a method which was pioneered by Bristol Aeroplane Company before the war, in order to prolong the lives of the heads of aero-engine valves working at high temperatures and in contact with leaded fuels. The process consists in coating with a nickel-chromium alloy (Brightray), which has good resistance to cracking at high temperatures and to corrosive attack. Use of a Brightray coating (applied by oxy-acetylene

welding) on the face of the anvil gives much improved life, and it is found that when the surface has become slightly damaged in use it may be re-ground and put back into service.

X-Ray Fluorescence Analysis of Nickel-Chromium-base Alloys

J. R. MIHALISIN: 'X-Ray Fluorescence Cuts Metal Analysis Time.' *Iron Age*, 1954, vol. 174, July 15, pp. 108–10.

The combined use of X-ray fluorescence and established methods of analysis has much reduced the time required for quantitative analysis of alloys used for the blades of gas turbines. This article describes methods employed at the plant of Curtiss-Wright Corporation, Wood Ridge, N.J., in the examination of alloys of the Nimonic 80 and 90 types: see Table below.

Alloy	C %	Si %	Mn %	S %	Cr %	Co %	Al %	Ti %	Fe %	Cu %	Ni %
Nimonic 80	0·10 max.	1·00 max.	1·00 max.	0·15 max.	19·0–22·0	1·00 max.	0·90–1·50	2·00–2·75	2·00 max.	— —	Bal.
Nimonic 90	0·10 max.	1·50 max.	1·00 max.	0·15 max.	18·0–21·0	15·0–21·0	0·80–1·80	1·8–2·7	5·0 max.	0·50 max.	Bal.

Iron and chromium in Nimonic 80, and iron, chromium, and cobalt in Nimonic 90 are quantitatively determined by means of X-ray fluorescence: the technique and equipment used are described. Comparison of results obtained by this method with those found by wet chemical procedures shows good agreement.

Reduction in time involved in analysis is significant: wet chemical methods would require 3½ hours for determination of iron and chromium in one sample of Nimonic 80, whereas X-ray fluorescence makes the analysis in 45 minutes. For Nimonic 90 the reduction in time for determination of iron, chromium and cobalt is from 8½ hours to 1 hour, and the test is non-destructive. When complete analysis is required the practice in the Curtiss-Wright Laboratories is to use wet chemical procedures for carbon, manganese, silicon and sulphur, and to estimate aluminium and titanium spectroscopically. Using the combination of the three methods, in place of complete wet chemical analysis, results in saving of 10 hours in a complete analysis of Nimonic 80 and 15 hours for a sample of Nimonic 90.

Oxidation Tests on Coated Molybdenum Wire

C. J. LEADBEATER and D. T. RICHARDS: 'Oxidation-Resistance of Diffusion Coatings on Sintered and Swaged Molybdenum Wire.'
Metal Treatment and Drop Forging, 1954, vol. 21, July and Aug., pp. 309–15, 387–96.

This paper reports experiments made in the Armament Research Establishment, Woolwich, to develop a method for inhibiting the severe oxidation which occurs when molybdenum is exposed to elevated temperatures.

The coatings used were of the following types:—

(1) *Metals:* aluminium, boron, beryllium, chromium, silicon, titanium, vanadium, zirconium.

(2) *Alloys* consisting of superimposed layers of individual metals: chromium-aluminium, aluminium-chromium, nickel-chromium, nickel-chromium-aluminium.

(3) *Metals subjected to surface treatments:*—
Boronized beryllium, titanium, zirconium, silicon, vanadium, chromium, nickel.
Siliconized titanium, vanadium, chromium, nickel.
Carburized boron, titanium, zirconium, silicon, vanadium, chromium.

The method of coating, by heating the wire in contact with a mixture of the appropriate metals and alumina, is described, and typical surface effects produced by the single and two-layer coatings are illustrated.

The tests to which the coated wires were subjected were of two types:—

(*a*) continuous heating in air at temperatures in the range 900°–1300°C.

(*b*) cyclic heating tests at 900°, 1000° and 1100°C. (made on aluminium-, silicon-, and zirconium-coated molybdenum only).

In the continuous tests the life of the molybdenum wire, for any type of coating, was not significantly affected until a minimum coating of 5 mg./sq. cm. had been deposited. As the weight of coating increased above this limit, the effects were as shown below:—

'(1) An immediate and substantial increase in life at a coating weight of 5–12 mg./sq. cm., e.g., silicon- and zirconium-coated wire heated at 1250°C. approximately; beryllium-coated wire at 1030°C., and nickel-chromium (40–60) alloy-coated wire at 970°C., also titanium-coated wire (12–20 mg./sq. cm.) at 1000°C. Some composite coatings, e.g., boronized beryllium, titanium and zirconium (more than 20 mg./sq. cm.), also showed extended life.

'(2) An intermediate prolongation of life at a coating weight of 12–20 mg./sq. cm., e.g., chromium, chromium-aluminium and nickel-chromium (80–20) coatings heated in the range 970°–1000°C., and titanium coatings heated at 1200°C.

'(3) A small improvement, at a coating weight in excess of 20 mg./sq. cm., was observed in boron-, aluminium-, and nickel-coated wires heated at 1000°C.

Raising the temperature above these ranges resulted in reduction in life of the coated wire, but silicon- and zirconium-treated specimens showed outstanding behaviour at 1300°C. Titanium and chromium-aluminium coatings were next in order of merit, performing well in the higher ranges of temperature.'

In the cyclic tests life was found to be prolonged with increasing weight of coating and with decreasing temperature of oxidation. The life values for all three types of coating und r cyclic conditions were shorter than under continuous heating: the decrease was least for silicon, intermediate for zirconium and greatest for aluminium coatings. Comparative tests on nickel-chromium-base alloys were made and the results are discussed in relation to the fundamental difference between oxidation of coated molybdenum and of heat-resistant materials such as the nickel-chromium-base series.

Resistance of Metallic and Non-Metallic Materials to Attack by Gallium

W. D. WILKINSON: 'Effects of Gallium on Materials at Elevated Temperatures.'
U.S. Atomic Energy Commission: Argonne National Laboratory Report 5027, Aug., 1953; 67 pp.

The work reported covers primarily an investigation of the relative tendencies of various metals and refractories to react with gallium at selected temperatures in the range 100° to 1000°C. or above; it deals also, in some cases, with attempts to inhibit such reactions.

It was known from the results of a preliminary survey of the literature that the following metals would be attacked by gallium at elevated temperatures: aluminium, cadmium, cerium, copper, gold, indium, iron, lead, magnesium, nickel, platinum, silver, lanthanum, tin, titanium, zinc, and zirconium. It was also known that copper is not appreciably attacked by gallium at room temperature. Except for a few check tests on a few of these metals, most of the experimental work therefore centred on other metals, including tungsten, rhenium, beryllium, tantalum, niobium, molybdenum, chromium, and manganese, as well as on a few binary alloys, and on stainless steels. Full details of all test conditions are given, and the results are summarized for each of the materials exposed. The conclusions drawn with regard to nickel-containing materials are briefly noted below:—

Resistance to Gallium at High Temperatures

Gallium alloys readily with nickel.

Stainless steels, both 18-8 chromium-nickel and straight-chromium types, react readily with gallium at 600°C.; niobium-stabilized 18-8 type and straight-chromium steel containing 14-18 per cent. chromium were, however, resistant to attack at 200°C. Inconel (nickel-chromium-iron alloy) was more severely attacked than 18-8 or straight-chromium steels.

An 80-20 nickel-tungsten alloy was completely disintegrated by heating in gallium at 600°C. for 330 hours.

Tungsten proved to be the only metallic element completely unattacked by gallium at temperatures up to 800°C.; rhenium was also practically unaffected at that temperature. Beryllium was next in resistance, being substantially unaffected at temperatures up to 500°C. Tantalum and niobium were unaffected up to 450°C.

Resistance to Gallium at Moderate Temperatures

Gallium has been suggested as a mild-temperature coolant in instruments and apparatus, e.g., round the rotating copper target of an X-ray machine, or in contact with stainless steel or with platinum plate in an 'enriched specimen irradiator'. Operating temperatures involved in such applications would be of the order of 100°-200°C.

To determine suitability for such service, specimens of straight high-chromium, and niobium-stabilized 18-8 steels, platinum, and copper were heated, at 100° and 200°C., in gallium for one month. The gallium was filtered from the specimens while at temperature, the filtrates were analyzed for dissolved metals, and the specimens were examined with regard to degree of attack. Niobium-stabilized 18-8 chromium-nickel steel proved entirely resistant; the high-chromium steel was practically so, although there was some evidence of incipient alloying reaction. Copper and platinum were severely attacked at 200°C., only moderately attacked at 100°C., and, by extrapolation, could be expected to show good resistance at room temperatures.

Nickel-Alloy Cast-Iron Pots for Melting Zinc Alloys

See abstract on p. 169.

Rare-Earth Additions to Stainless Steels

R. H. HENKE and R. A. LULA: 'Rare Earths Counteract Hot Rolling Defects in Stainless Steel.'
Jnl. of Metals, 1954, vol. 6, Aug., pp. 883-8.

The rolling qualities of stainless steel are determined by a number of metallurgical factors, chief of which are the structure and grain size of the ingot, pouring temperature, the influence of additions of small amounts of special alloying elements, and the phase in which the steel has solidified (ferritic or austenitic). This paper discusses the 'rollability' of straight-chromium ferritic and martensitic, chromium-nickel austenitic, two-phase complex chromium-nickel, and chromium-manganese steels.

The martensitic and ferritic steels hot-roll easily and no special additions are required to promote workability. In 27 per cent. chromium steel some austenite may form, but this can be overcome by addition of ferritizing elements, e.g., aluminium. Austenitic steels are more difficult to hot-roll, being characterized by two types of hot-shortness, one due to a duplex austenite-ferrite structure, the other inherent in the higher-alloyed steels of this type. Hot-shortness due to duplex structure can be prevented by correct balance of the constituent elements, by judicious selection of the hot-rolling temperature, and by soaking for adequate periods at suitable temperatures prior to hot-rolling. Diagrams in the paper illustrate the influence of balanced composition and of heating conditions, on hot-working quality, and photomicrographs show typical structures associated with lack

of hot-ductility resulting from the presence of excessive amounts of ferrite.

The inherent hot-shortness found in the higher-alloy austenitic stainless steels increases with the size of the ingot, and is considered to be related to coarseness of grain. Addition of a deoxidizing ferro-alloy, containing substantial proportions of titanium and aluminium, effects some improvement, but hot-shortness is best counteracted by the addition of rare earths, in metal or oxide form. Experiments with rare-earth metals (results of which are recorded in this paper) showed that best results are obtained by the use of 4–5 lb. per ton of steel. Such additions tend, however, to impair the cleanliness of the steel: impurities resulting from them segregate close to the surface of the ingot, giving rise in the finished sheet material to a defect designated 'hairs'. These 'hairs' are associated with cracking during upsetting of bar.

In view of these findings, and in the interests of economic production, experiments have been made with rare-earth oxides. When used in amounts of about 3 lb. per ton, in steel already treated with a deoxidizing ferro-alloy, or to the extent of 5 lb. per ton in steel not previously treated with a special deoxidizer, highly successful results are obtained. Cerium is the most potent constituent in the rare-earth oxide addition, and there appears to be, from the point of view of hot-workability, an optimum amount of rare-earth oxide addition, expressed as 0·036–0·040 per cent. cerium.

Work carried out by the Allegheny-Ludlum Steel Corporation has proved the use of rare-earth oxide additions to be so advantageous that it has been adopted as standard in their plant, where by this means ingots for which a two-stage conversion was previously necessary can now be hot-rolled in a single stage. Ingot yield has also been markedly improved by this treatment.

The modification produced by the rare-earth metal and oxide additions appears to be related to increased ductility at the rolling temperature, but the exact mechanism of the effect is not yet fully understood.

Influence of Cold Work on Transformations in Austenitic Steels

B. CINA: 'Effect of Cold Work on the γ–α Transformation in Some Fe-Ni-Cr Alloys.'
Jnl. Iron and Steel Inst., 1954, vol. 177, Aug., pp. 406–22.

Although the term 'stainless steels' now covers a wide range of composition, the steels falling within the limits 18–25 per cent. chromium and 8–12 per cent. nickel constitute the majority of the stainless types commercially produced. Moreover, in this range of composition the 'balancing' of alloy components vitally affects stability, and it is therefore of importance that the influence of the alloy elements involved should be precisely known, as affecting the behaviour of the steels on heat-treatment and mechanical processing.

It is well known that retained austenite in such materials can be made to transform to α-ferrite by application of cold work, a characteristic which offers a convenient method of obtaining a quantitative measure of the metastability of the austenite in any steel by determining the percentage of austenite retained after suitable heat-treatment and various conditions and degrees of cold work.

The work reported in this paper consisted in a study of the effect of cold work on iron-nickel-chromium alloys within the range of composition referred to above, with particular reference to the individual effects of nickel and chromium. The compositions of the individual materials tested are shown in the Table below.

The report of the experimental work, on the combined effects of the elements concerned, is preceded by a review of the literature relating to the separate effects of chromium and of nickel, on iron. The review is supported by an extensive selective *bibliography*.

In the work on the ternary alloys, constitution was determined after quenching from elevated temperature to room or sub-zero temperatures, and after deformation at room temperature. Based on the observations

Analysis of Alloys Studied

Nominal Composition	Composition, wt.–%												
	C	Si	Mn	Al	S	P	Cr	Ni	Mo	Ti	O	N	H_2*
16/8 Cr-Ni	0·0015	0·09	<0·02	0·06	0·006	<0·005	16·25	8·24	—	—	—	0·005	—
18/8 Cr-Ni	0·0097	<0·01	<0·02	<0·02	0·003	<0·005	18·01	8·14	—	—	0·11	0·009	0·7
18/12 Cr-Ni	0·0017	0·09	<0·02	<0·02	0·005	<0·005	16·74	12·57	—	—	0·013	0·009	0·8
25/12 Cr-Ni	0·0074	0·05	<0·02	<0·02	0·004	<0·003	25·41	12·26	—	—	0·17	0·007	1·2
18/8/0·1 Cr-Ni-C ..	0·12	0·55	0·34	<0·02	0·019	0·020	17·86	7·9	0·34	—	—	0·029	—
18/12/0·1 Cr-Ni-C ..	0·12	0·46	0·27	<0·02	0·020	0·022	17·2	12·58	0·51	—	—	0·037	—
25/12/0·1 Cr-Ni-C ..	0·11	0·55	0·35	0·02	0·014	0·014	24·18	12·43	0·36	—	—	0·110	—
18/8/0·12/0·6 Cr-Ni-C-Ti	0·12	0·74	0·40	0·05	0·013	0·014	18·12	8·18	<0·02	0·61	0·003	0·007	1·0
19/10/0·02 Cr-Ni-C ..	0·02	0·38	0·88	0·02	0·016	0·010	19·2	10·0	<0·02	—	0·006	0·037	2·8

* Hydrogen contents are quoted in ml. per 100 g.

made, extensive details of which are given in the paper, the author makes the following summary:—

'Constitution of pure 16-8, 18-8, 18-12, and 25-12 chromium-nickel iron-base alloys was determined after quenching from elevated to room and to sub-zero temperatures. The 16-8 alloy had transformed fully and martensitically from γ to α_2 by the time it had reached room temperature. The 18-8 alloy was almost fully transformed under the same conditions and in addition revealed a new phase of hexagonal close-packed structure, transient in character, analogous to the ε phase in iron-manganese alloys, and here called θ. The 18-12 and 25-12 alloys were fully austenitic and duplex ($\gamma+\delta$), respectively, on quenching to room temperature, but the former underwent partial transformation to α_2 and θ at sub-zero temperatures.

'(2) The metastability of austenite on quenching to room temperature or sub-zero temperatures is related to alloy content such that both nickel and chromium depress the M_s, M_d, and M_f of the γ-α_2 transformation when present together.

'(3) The effect of cold work was to transform metastable γ to α_2 or ($\alpha_2+\theta$). The extent of transformation with cold work can be used as a criterion for γ stability only in so far as it indicates the degree of undercooling below M_d. The extent of transformation increased with cold work and lower temperature, although less transformation could be induced by compression at $-152°$ than at $-67°$C.

'(4) The marked difference in γ stability between pure and commercial alloys can be related to the depressing effect, on M_s and M_d, of the additional alloying elements (carbon, nitrogen, manganese, etc.) in the commercial alloys.

'(5) Samples deformed in tension transformed to a greater extent than those deformed equally in compression. Compressive stresses oppose the volume expansion accompanying the transformation and may also orientate the γ less favourably than tensile stresses, so reducing the effective resolved shear stresses available for the transformation.

'(6) The occurrence of the θ phase as an intermediate stage in the transformation γ-α_2 offers another mechanism for the crystallography of the latter change.

'(7) The extent of martensitic transformation of γ to α_2 or θ was found to increase the greater the quenching stresses.

'(8) Isothermal martensite formation of α_2 was observed in both quenched and furnace-cooled pure 16-8 and 18-8 alloys.

'(9) No stabilization effects could be detected in any of the pure alloys.

'(10) A hysteresis of about 400–800 C.deg. was observed for the $\gamma \rightleftharpoons \alpha_2$ transformation in pure 16-8 and 18-8 alloys. The transformation $\alpha_2 \rightarrow \gamma$ occurred over the range 500°–800°C., and not at one fixed temperature.

'(11) The microstructure of α_2 formed by quenching in pure 16-8 and 18-8 alloys was akin to that observed in iron-nickel alloys. The α_2 phase formed by deformation occurred as laths on the crystallographic planes of the γ. Coarse-grained samples revealed that the α_2 could be nucleated at grain or twin boundaries or randomly within the grains. The existence of a critical resolved shear stress for the γ-α_2 transformation was indicated.

'(12) The extent of work-hardening of iron-nickel-chromium alloys of the foregoing types is proportional to the percentage of the high work-hardening face-centred cubic γ phase present and the carbon content of the martensitic α_2 phase formed, if any.'

Physical Methods for Determination of Austenite and Martensite Contents of Stainless-Steel Wire

S. STORCHHEIM: 'Non-Destructive Test Gives Austenite, Martensite Percentages.'
Iron Age, 1954, vol. 173, July 1, pp. 108-11.

The author gives details of a method which combines measurement of remanence and coercive force with examination by X-ray diffraction technique. Its applicability is illustrated by reference to results obtained on specimens of 18-8 chromium-nickel steel wire cold-drawn to various stages of reduction.

Compression Yield-Stress Tests on Steels and Non-Ferrous Alloys

See abstract on p. 169.

Nickel and Nickel Alloys in Chemical Engineering

5th Symposium on Constructional Materials for the Chemical Industry.' *Reprint from De Ingenieur*, 1954, Nos. 16, 18, 20 and 22; 40 pp.

The reprint contains papers and discussion presented at a Symposium held in The Hague in November 1953. Individual contributions are listed below:—

E. F. BOON and A. J. FLEUREN: 'Fundamental Requirements for Lining Materials.'

The types of corrosion-resisting material which may be used for linings are listed, and their properties are discussed in relation to the requirements of the chemical industries. Among the materials considered are corrosion-resisting steels, lead, nickel, Monel and Hastelloy-type alloys. Primary considerations in assessing the suitability of lining materials include corrosion-resistance, thermal-expansion characteristics, long-term properties under stress at elevated temperatures, thermal conductivity, and freedom from porosity.

G. T. KETJEN: 'Lead as a Constructional Material for Chemical Equipment.'

A survey of properties and uses.

L. VAN DER EIJK: 'Lead as a Cladding Material (in the Rayon Industry).'

E. J. BRADBURY: 'Nickel- and Monel-Clad Steel in the Chemical-Engineering Industry.'

The thermal and mechanical properties of nickel and Monel are reviewed, with particular reference to their significance in the production of clad steel. Attention is directed to specifications drawn up by the British Standards Institution, the American Society of Mechanical Engineers, and other standardizing authorities, to govern the use of clad steels in pressure

vessels. Secondly, a review is made of the corrosion-resistance of nickel and Monel, under (1) conditions of dry corrosion (oxidation, sulphidation, attack by other gases, and exposure to molten metals), and (2) in service involving wet corrosion, e.g., contact with fresh or salt water, neutral and alkaline salts, acid salts, oxidizing acid or alkaline salts, mineral acids. and alkalis. Graphs and tables illustrate the useful degree of corrosion-resistance which can be obtained by the use of Monel- or nickel-clad steel in various conditions typical of those encountered in the chemical-engineering industries. The next section of the paper is concerned with cold- and hot-working processes suitable for processing these materials. Arc welding is also considered. Finally, the author deals briefly with considerations involved in design and use of plant incorporating nickel- or Monel-clad steels.

B. GOEDHUIS: 'Stainless-Lined and Stainless-Clad Steel for Pressure vessels.'

Formulae are presented for calculation of stresses set up on heating of stainless-lined or -clad steel components. Experience gained in the use of a clad-steel reactor in a catalytic cracking plant is discussed.

H. C. GEERLINGS: 'Stainless Steel as a Lining Material for Protection against Corrosion.'

Various methods for the lining of chemical vessels are described, and the influence of the type of welding rod, on the structure of the stainless-steel weld metal, is illustrated by reference to the Schaeffler diagram. A report is given of tests made to determine the influence of width of strip used for lining, and a note is added on costs.

Gaskets for Use with Stainless Steel

E. V. KUNKEL: 'Selecting Gaskets to Limit Corrosion of Stainless Steel Bolted Joints in a Chemical Plant.' *Corrosion*, 1954, vol. 10, Aug., pp. 260-6.

The author draws attention to the serious loss to industry, and danger to personnel, arising from corrosion of stainless-steel joint surfaces by liquid media which penetrate contacting gaskets. This type of attack is a common occurrence in piping, heat exchangers, fractionation towers, extractors, and vessels: its nature is illustrated in this paper by photographs of stainless-steel surfaces which have been in contact with rubber-asbestos gaskets in plant handling various corrosive media. Six stages of deterioration are shown, ranging from incipient corrosion through to an advanced condition: in each case details are given of the corrosive medium involved. All the gaskets were of rubber-asbestos composition.

It has been observed that gasket bearing surface corrosion is normally encountered in austenitic stainless steel under conditions which have a tendency to produce a pitting type of corrosion and/or to set up active corrosion cells. In general, it is found where the liquid being handled is of high electrical conductivity and contains weak oxidizing and reducing agents co-existing in the process media, but mild attack may occur in other circumstances. Other factors, such as the presence of chlorides, or of other materials capable of breaking down the passive film, also exert a definite influence in relation to this type of corrosion. The author gives a summary of typical media in contact with which the deterioration has been observed.

The following theory is advanced to explain the corrosion attack encountered in the conditions described:—

In conventional joints the asbestos fibres of the gasket material are in contact with the gasket bearing surface and with the process material being handled. A figure in the paper illustrates how the process liquid may seep, following the lines of the asbestos fibres, which act as wicks, with the result that moisture is gradually drawn out and stagnant pools of liquid are formed on the gasket surface. These pools create active-passive and/or oxygen-concentration cells, with the whole of the inside surface of the equipment concerned acting as a cathodic area. In aerated solutions, oxygen, if present, may act in its rôle as a cathode depolarizer. With the unfavourable area relationship of anode to cathode areas thus set up, attack can progress very rapidly once corrosion action has been established. Other factors, such as ion concentration cells and differentials in pH between the points of stagnant liquid in the gasket surface and the moving liquid inside the equipment, may stimulate and increase the rate of attack.

Following this theory, the author has developed a method for inhibiting corrosion of the type described. It is based on the principle of placing a physical barrier between the surface of the gasket material and the process liquid, to prevent formation of the pools of stagnant liquid on the bearing surface. Practical interpretation of this idea comprises the use, for gaskets, of Neoprene, rubber, or other materials which are free from constituents which can act as wicks, or of asbestos-containing masses so designed that the surfaces in contact with the gasket bearing are continuously non-fibrous. In such asbestos-composition media, those having a high binder-to-asbestos ratio are to be preferred to those of lower binder content. Test exposure of the various forms of gasket is described and the condition of the respective types after test is illustrated. It is emphasized that correct design of joint, as well as suitability of gasket material, is a vital factor in ensuring satisfactory resistance of the stainless steel surfaces to corrosion. Concise recommendations on joint design are made in the paper.

Stainless-Steel-Faced Aluminium Sole Plate for Laundering Irons

'New Method to Bond Steel to Aluminum.' *Precision Metal Molding*, 1954, vol. 12, May, pp. 49-50; see also *Nickel Topics*, 1954, vol. 7, No. 6, pp. 1, 4.

By means of a process patented by the Al-Fin Division of the Fairchild Engine and Airplane Corporation, a thin layer of nickel-chromium stainless steel is bonded to the bottom of the conventional aluminium soleplate of domestic irons, giving freedom from discoloration, sticking, etc., which may occur when aluminium soleplates are in contact with damp and/or starched fabrics. Production of the faced plates is illustrated.

Liquid Metal Fuel Reactor Systems: Design and Materials of Construction

Nucleonics, 1954, vol. 12, July, contains a series of seven articles giving 'the most comprehensive study at present available of power reactor design'. The all-over advantages of such power reactor systems are listed and individual aspects of the subject are considered. Materials of construction used for components in the respective plants described are discussed, e.g., the uses of austenitic nickel-chromium steels; nickel; high-chromium, chromium-molybdenum, and chromium-silicon steels, and other metallic materials.

Addenda

Nickel Bulletin, July/Aug., 1954:

p. 158, Nickel-base Pen-Nib Alloys: *add* Brit. Pat. 707,082.

p. 159, Temperature-Compensating Alloys, second patent: *add* German Pat. 899,360.

p. 160, Nickel - Chromium - Manganese Brazing Alloys: *add* Brit. Pat. 707,078.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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